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ABSTRACT

The combination of the costs of providing services in sparsely populated areas and the equal opportunity benefits of comprehensive schools generates problems in terms of school district organization. The research reported here examines the relationship between increasing school district enrollment and increasing the distance children have to travel to school. Using a location-allocation methodology, the researchers examined four enrollment levels to find out how much distance would have to increase if reorganization were to occur at any of the target figures (namely, 1,000, 750, 600, and 400 pupils per school district). The results of the study showed that the average distance increase for children would be minimal, simply because most children would not be affected. However, among reassigned children the impact would be significant, averaging more than 10 miles for most alternatives. If reorganization were to occur, the study recommends, small marginal increases in distance would result from setting enrollment minima at 1,000 or 750 pupils rather than 600 or 400. More attractive than a single enrollment standard, however, would be a combination of enrollment and distance standards. (Author/LD)

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DISTANCE EFFECTS OF SCHOOL DISTRICT REORGANIZATION

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March 1978

Final Project Report No. 16

Institute of Urban and Regional Research
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PREFACE

The State of Iowa Department of Public Instruction is involved in a multi-faceted analysis of Equal Education Opportunities in the state. One of DPI's concerns is the possibility of reorganizing school districts so that all children would be provided a breadth of educational choices. Enlarging the sizes of the smallest districts in the state is one way of increasing the likelihood that all children will have adequate educational opportunities. Increasing district size, however, increases distances as well as enrollments. In order to understand the relationship between increases in enrollment and requisite increases in distance, DPI contracted with the Institute of Urban and Regional Research, University of Iowa, to study the distance effects of implementing alternative enrollment minima. We accepted with relish the opportunity to conduct the study.

Completion of the research was enhanced by assistance from several sources. Dr. Leland Tack and his staff at DPI provided the input data and much of the direction for the analysis; Kenneth J. Dueker at the Institute of Urban and Regional Research and Lyell Henry at University House, University of Iowa, provided facilities. The results of the analyses, of course, are the responsibility of the authors.

Rex Honey
James A. Kohler

Contents

	Page
INTRODUCTION	1
PROBLEM IN IOWA	2
METHODOLOGY	6
Assumptions	7
Data	9
DISTANCE EFFECTS OF ACHIEVING ENROLLMENT MINIMA	10
Average Student Travel Distance	11
Average Distance Among Affected Students	14
Maximum Student Travel Distance	14
OPTIMAL SOLUTIONS	16
400 Pupil Solution	16
600 Pupil Solution	19
750 Pupil Solution	19
1,000 Pupil Solution	19
SET COVERING SOLUTIONS	22
DISTANCE-ENROLLMENT TRADEOFF	25
Urban Separation Solution	26
Constraint Relaxation Solution	26
EFFECTS OF COUNTY SCHOOL DISTRICTS	30
SUMMARY	33
NOTES	36

List of Figures

		Page
1.	Distribution of Projected Enrollments (in increments of 50)	5
2.	Minimum School District Size	12
3.	Average Student Travel Distance	13
4.	Average Student Travel Distance from Outlying, Original School Districts to Consolidated School	15
5.	Maximum Student Travel Distance	17
6.	328 Districts - Enrollment Greater than 400; Maximum Distance = 20 Miles	18
7.	242 Districts - Enrollment Greater than 600; Maximum Distance = 22 Miles	20
8.	203 Districts - Enrollment Greater than 750; Maximum Distance = 22 Miles	21
9.	146 Districts - Enrollment Greater than 1000; Maximum Distance = 26 Miles	23
10.	Increasing Distance with Increasing Enrollment	24
11.	Districts with 1,000 Enrollment in 10 Miles	27
12.	Districts with 750 Enrollment in 15 Miles	28
13.	Districts with 600 Enrollment in 20 Miles	29
14.	164 Districts (Constraint Relaxation); Maximum Distance = 25 Miles	31
15.	Distances Children Would Travel to School -- All Options	32
16.	Maximum Distances from County Seat or Surrogate in Iowa's Most Sparsely Populated Counties	34

INTRODUCTION

The social costs of transportation and accessibility complicate provision of services in sparsely populated areas. Private enterprise simply neglects areas with insufficient market demand to pay for goods and services. Many public services, however, must be made available to everyone, particularly when the service is as fundamental as education.

Indeed, equalization of educational opportunity has become a major social goal for education in recent years. Perhaps stimulated by the writings of such leaders as James Conant, many educational administrators (and the courts) have adopted a view that each child should have an individually appropriate education, independent of the needs and number of the child's neighbors. Such a view leads to advocacy of comprehensive schools with a breadth of opportunities ranging from rigorous preparation for college to marketable manual skills. Genuinely comprehensive schools, of course, have a sizable fixed cost in that they require the trained teachers and proper equipment necessary to execute the curriculum.

The union of the costs of providing services in sparsely populated areas and the equal opportunity benefits of comprehensive schools generates problems in terms of school and school district organization. In sparsely populated areas there are two primary ways to organize school districts in order to provide a comprehensive curriculum, and each way has inherent costs. If districts are small, the fixed cost of comprehensive education per child is high, therefore education will either be excessively expensive or not comprehensive. If districts are geographically large in order to attain certain enrollment limits, both time and monetary costs of transportation would be high, and some of the social benefits of having a local school would be lost for many of the pupils.

What is the relationship between increasing enrollment limits of school districts and extra distance children would have to travel to school? The answer is, of course, a function of population density, among other things. Given a population distribution, the distance children must travel to school is likely to increase as the minimum number of children required for a school district is increased. The greater the population density, the less an increase in enrollment limits is likely to increase trip length, simply because a smaller increase in district area will generate the requisite enrollment increase. Using the State of Iowa as the study area, this research examines the relationship between increasing district enrollment and increasing the distance children would travel to school. In addition to increasing knowledge about spatial relationships, the research should make it possible for the people of Iowa and their elected and appointed representatives to make more rational, informed decisions. Thus when alternative proposals for adjusting school district limits are made, the consequent increases in distance can be known. With this knowledge in hand, the people of Iowa will be better equipped to decide if the advantages of increasing the enrollments of some school districts are worth the increases in distance which would likely accompany school district reorganization. The product of this research is not a recommendation and should not be construed as such; it is a statement about the distance consequences of some school district reorganization alternatives.

PROBLEM IN IOWA

Through the years the number of school districts in Iowa has dropped dramatically. As the one classroom, independent district yielded to the kindergarten through twelfth grade districts with varied programs, the number of districts plummeted from the thousands to the hundreds. Major "consolidations" of districts occurred in the 1920's and 1950's, but a trickle of reorganizations continue. Since 1968 twelve districts have reorganized into six

new districts, dropping the Iowa school district roster to 499. School district reorganization transpired for two chief reasons: educational needs and preferences of the society changed so that the smallest schools lost favor relative to somewhat larger ones; and because the number of children in Iowa declined. On a national scale, Iowa's shift toward larger districts did not mean large districts, just larger than before. A majority had fewer than 600 pupils, i.e. fewer than 50 per grade. Iowa's school-aged population declined because of long-term out-migration and a reduction in the number of births in the state -- demographic circumstances which have recently reversed themselves, with the reversals not expected to "replenish" the State's crop of children. Three-quarters of Iowa's districts have fewer children this year than last, and the prospect is for more decline at least for five years and probably much longer.

Many of Iowa's school districts find themselves in a financial vise. Several factors contribute to the squeeze, among them the commitment to equal educational opportunity. To meet the equity commitment, the State has assumed financial responsibility for a greater and greater portion of school district expenditures. Meanwhile, to placate taxpayers the State limited the amount of money districts may levy locally, thus placing a ceiling on district budgets. Simultaneously the State requires provision of a range of courses to assure that the needs of all children are met. With budgets tied to enrollment and with virtually fixed costs for fulfilling the State mandated curriculum, small school districts find themselves in a squeeze, particularly if their enrollments are declining, as is typically the case.

A simple remedy to the fiscal squeeze would be further school district reorganization. Districts which are too small now and shrinking could join together so that they would assure themselves adequate enrollments for the future. Aside from the arguments for keeping school as close to home as possible

(and these arguments will not be addressed here, not because they are necessarily wrong but because they should come subsequent to the findings of this study rather than independently of the facts about distance) a problem confounding further school district reorganization is the highly uneven distribution of Iowa's population. Despite its image as a rural state, over half of Iowa's residents are classified as urban by the Bureau of the Census, and over half the population lives in fifteen of Iowa's 99 counties. The distribution of school children is equally concentrated with half the pupils living in about one-sixth of the districts and the other half the other five-sixths. Consequently school district reorganization, in order to meet minimal enrollments so that the fiscal pressure is alleviated, is most needed in the most sparsely populated areas. Joining a rural district with a neighboring urban one may achieve the desired results with limited increases in travel distances. On the other hand, joining rural districts with each other could produce excessive trip lengths, unless innovative administrative practices enable the district to attain the economies of reorganization while maintaining more than one school for each level. (A district could, for example, move teachers rather than pupils or adopt audio-visual and computer assisted instructional innovations.)

Declining enrollments are likely to make the financial health of many Iowa school districts increasingly precarious. Projecting school district enrollments is notoriously difficult, especially beyond five years in the future when numbers of future births must be estimated, but working with the state as a whole and only with children actually born, useful projections for the 1981-82 school year can be made. For that year, the DPI projections show that many school districts will experience severe enrollment declines (Figure 1). One district is expected to drop below 100 pupils, and scores of others are expected to

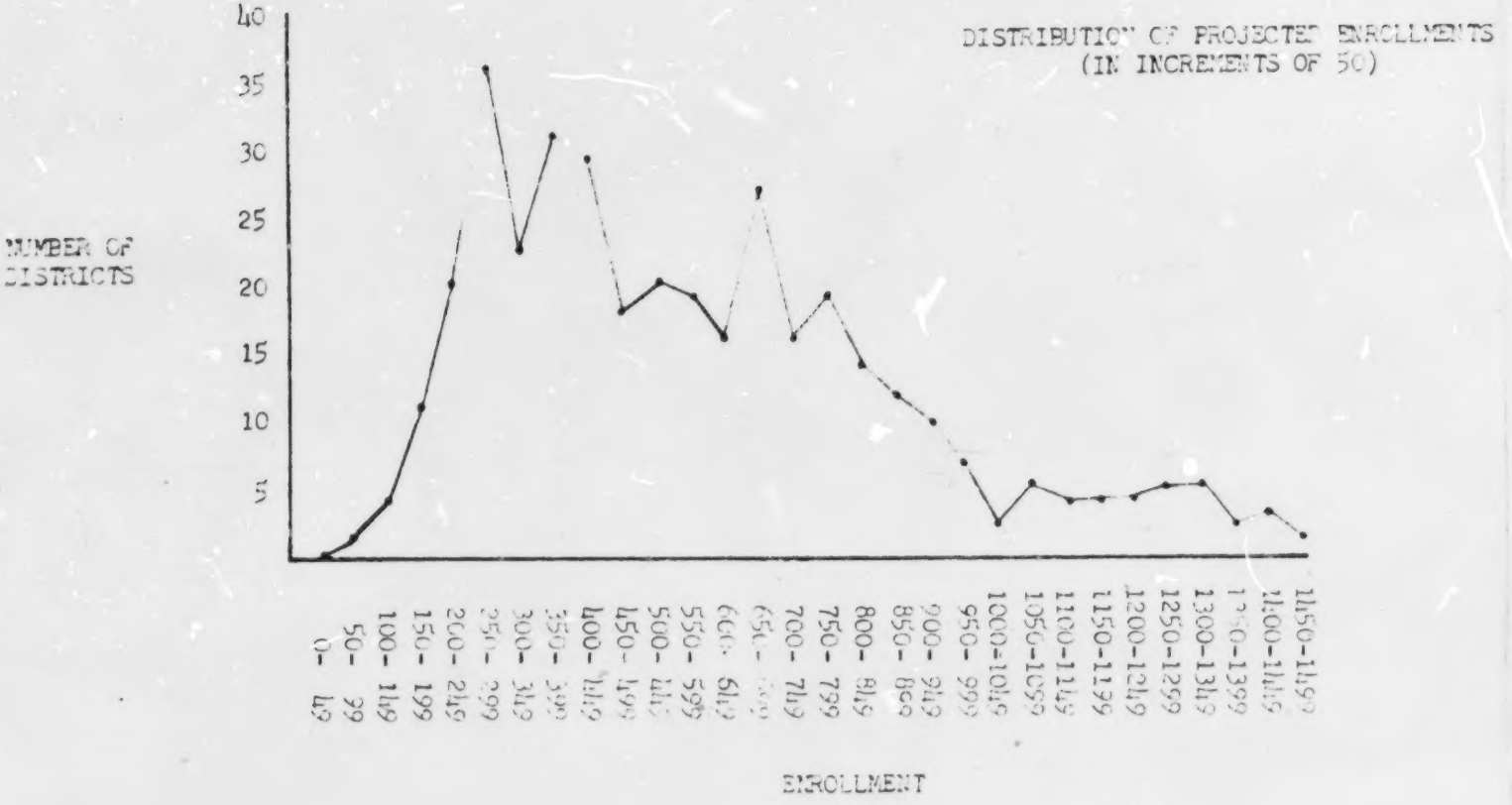

DISTRIBUTION OF PROJECTED ENROLLMENTS
(IN INCREMENTS OF 50)
NUMBER OF DISTRICTS
40
35
30
25
20
15
10
5
0- 49
50- 99
100- 149
150- 199
200- 249
250- 299
300- 349
350- 399
400- 449
450- 499
500- 549
550- 599
600- 649
650- 699
700- 749
750- 799
800- 849
850- 899
900- 949
950- 999
1000-1049
1050-1099
1100-1149
1150-1199
1200-1249
1250-1299
1300-1349
1350-1399
1400-1449
1450-1499
ENROLLMENT

Figure 1

have fewer than 300. Hence the problem of having extremely small districts is likely to increase, and this in turn has generated increased interest, especially among those committed to educational equity in reconsidering the organization of school districts in the state.

Over the past several years several target figures for school district enrollments have been bandied about by the Iowa news media -- reorganizing districts so that no district has fewer than 400, 600, 750, 1,000 pupils, or switching to one district per county. Generally these suggestions have been presented with arguments about the likely consequences, both good and bad. The likely consequences, however, have been educated guesses rather than the product of rational, objective research. What follows is an attempt to lend some objectivity to what is frequently a highly emotional, hotly subjective debate. It is an effort to calculate the distance consequences of reorganizing school districts in Iowa along a number of suggested lines.

METHODOLOGY

For the most part, location-allocation methodology was followed in this research. Location-allocation algorithms allow analysts to solve problems involving the locations of facilities and the assignment of users to facilities. ALLOC 6, a highly flexible location-allocation algorithm developed in the University of Iowa's Department of Geography, was used to solve most of the problems in this research. In the first set of analyses, the logic was to find combinations of existing school districts which could all meet a specified enrollment minima in such a way that the total travel distances for children would be minimized. In this way, the least distance solution for each enrollment minimum could be determined, enabling a comparison of the extent to which distances would increase as the enrollment minimum was forced up. This set of analyses emphasized enrollment constraints and observed changes in distance as enrollment was changed. The

simplifying assumptions which allowed completion of these analyses are discussed momentarily.

A second set of analyses emphasized the importance of distance, setting distance constraints and seeing how enrollment varied as distance was changed. This set of analyses was conducted in order to provide a comparison with the enrollment-constraining first set. The distance-constrained analyses were completed by solving location-allocation's set covering problem, i.e. by finding the smallest number of facilities which will allow all demand (in this case existing school districts) to fall within a maximum distance constraint of the nearest facility.

The first two sets of analyses examined extreme results, each taking one of two important variables and seeing how the second changed and the first was manipulated. The third set of analyses followed a different approach. In it, both distance and enrollment size were regarded as important, and the two variables were "relaxed" simultaneously in the solutions in order to accomplish a trade-off between them.

Finally, a totally different alternative was considered, scrapping existing school districts in favor of one district for each county. The extent to which both enrollment and distance criteria could be met with such a switch was examined.

Assumptions

Whenever a problem is as large as the one considered, a number of simplifying assumptions must be made. The assumptions are required because they can reduce an enormous task to a manageable one; but they also must be realistic enough that they do not invalidate the analysis. Unrealistic assumptions can yield unrealistic results. On the other hand, what may appear to be unrealistic assumptions may enhance the analysis without jeopardizing the validity of the results.

The primary reorganization assumption was that change in district definition would be accomplished only by consolidation of existing districts. No districts would be split in the analysis, two or more parts joining separate districts. If reorganization were to occur, this would be a viable assumption for district change. Most reorganization in the past was accomplished by consolidation, an important advantage of which was the case for determining responsibility for bonded indebtedness. Obviously in reality this assumption has been violated. An example of such a violation occurred in 1977 when one small district considered dissolving so that sections could join three other districts as an alternative to consolidation with a neighboring district. Violations aside, the assumption should hold in most cases, and any mismeasurement because of the assumption was likely to be negligible. In addition, the assumption was necessary because enrollment data were available only for a school district as a whole rather than for portions of districts. The data limitations thus precluded use of data units finer than entire districts.

The second assumption was that districts would use existing facilities only, building no new schools. This assumption was reasonable because the advantages of reorganization would be lost if new construction were required.

The data limitations force use of the third assumption, which was that the important distances were those from a student's existing high school to a newly assigned high school, with the distance between home and a pupil's existing high school ignored. While the data forced use of this assumption, it was in fact a better measure than it may sound at first. What was important in the analysis was not so much the total distance children would travel in a reorganized system but rather the increase in distance which would result from reorganization. Following from the first two assumptions, i.e. reorganization by consolidation only and use of existing facilities, one current district would be likely to have retained use of its high school in each new district.

The other current districts would have had their children bussed to that high school. Given the way high schools are located within existing districts, which is to say fairly centrally in most cases, the distance between the existing high school and the new high school was probably a quite accurate reflection of the average distance students' homes would be from the new high school. About as many students would have lived between a pair of schools (and therefore have their distances overestimated) as would have had to travel past the old school to get to the newly assigned school (and therefore have their distances underestimated). Thus the high school to high school measure was a reasonable one with which to capture the increases in distance generated by reorganization.

A fourth assumption also dealt with distance. It was included because it added computational simplicity and realism to the analyses. The assumption was that all travel was along north-south and east-west routes. Given Iowa's rectilinear road grid, this was a highly realistic assumption. The few instances in which diagonal roads reduced distances or circuitous roads increased them were unlikely to affect the results significantly, in part because they had countervailing influences on distance and in part because they were so few in number.

Data

The input data for the analyses were in fact quite simple. The pertinent data included locational identifiers (with both north-south and east-west coordinates) for each of the state's 449 school districts, along with the 1981-82 "conservative" projection provided by the Department of Public Instruction. DPI's conservative projection was largely dependent on a cohort-survival method with only minor consideration of likely migration.

DISTANCE EFFECTS OF ACHIEVING ENROLLMENT MINIMA

Four target enrollment levels were examined in order to find out how much distance would have to increase if reorganization were to occur at any of the target figures. The four were 1,000, 750, 600, and 400 pupils per school district. In each case, Iowa school districts were grouped in such a way that all districts would have at least the minimum population and so that the total increase in the distance of moving children to school would be minimized. The mathematical objective function, then, was to minimize total travel.[1] The target enrollments operated as constraints on the solution.

In order to expedite progress toward a solution, as well as to yield more information for considering the relationship between enrollment size and distance, the solution for each enrollment target was found in a series of steps. The first step simply found all districts projected to meet the target figure in 1981-82 and then assigned all remaining school districts to the closest one meeting the target. Thus the 1,000 solution had 116 districts; the 750 had 178; the 600, 222; and the 400, 333. These assignments, which were obviously unsatisfactory because of the great distances involved, merely provided starting points. The second step added five districts to the number in the first. The algorithm searched the possible combinations to find which set of locations and allocations would minimize total distance for the specified number of centers. The third step added five more districts, again finding the optimal locations and allocations. As the number of districts increased, the distances of students to assigned school decreased. Likewise, the enrollment of the smallest school in a solution tended to decrease. This incremental process, adding five districts each step, was repeated until no more districts could be added without having a minimum distance solution with some districts falling below the

target level. Thus it was found the the maximum number of districts above 1,000 pupils would be 146, given a minimum total distance objective function. If an enrollment of 750 were the minimum, the maximum number of districts would be 203. For an enrollment level of 600, the districts would number 242, and if enrollment dropped to 400, the number of districts would have to increase to 328. If these enrollment targets were maintained, the only way that additional districts could be added would be to increase distances children would travel. In order to yield more information about the relationship between enrollment size and distance, the incremental procedure was continued for a few steps even though the solutions then had some districts with fewer than the requisite enrollments (Figure 2). This way the amount of decrease in distance could be compared with the amount by which some districts fell below the target enrollment. In order to expedite interpretation of the results of these analyses, the results are presented graphically in several different ways below.

Average Student Travel Distance

Considering all students in the state, reorganization of school districts to meet the four target enrollment criteria need not require what appear to be excessive increases in distance (Figure 3). The optimal set of assignments with the 1,000 pupil enrollment constraint would increase travel only 3.5 miles per pupil. The 750 pupil minimum would require a 2.5 mile per pupil increase. The 600 and 400 pupil solutions would force increases of just over and just under one mile per pupil, respectively. In terms of distance, reorganization so that all districts would have at least 400 children offers scant advantage over a reorganization up to a 600 child minimum. In terms of increased distance, the 750 enrollment figure is better than the 1,000 pupil solution by only about as much as the 400 enrollment figure is better than the 600 pupil solution. Each move to a higher enrollment adds an average of one mile to each student's travel.

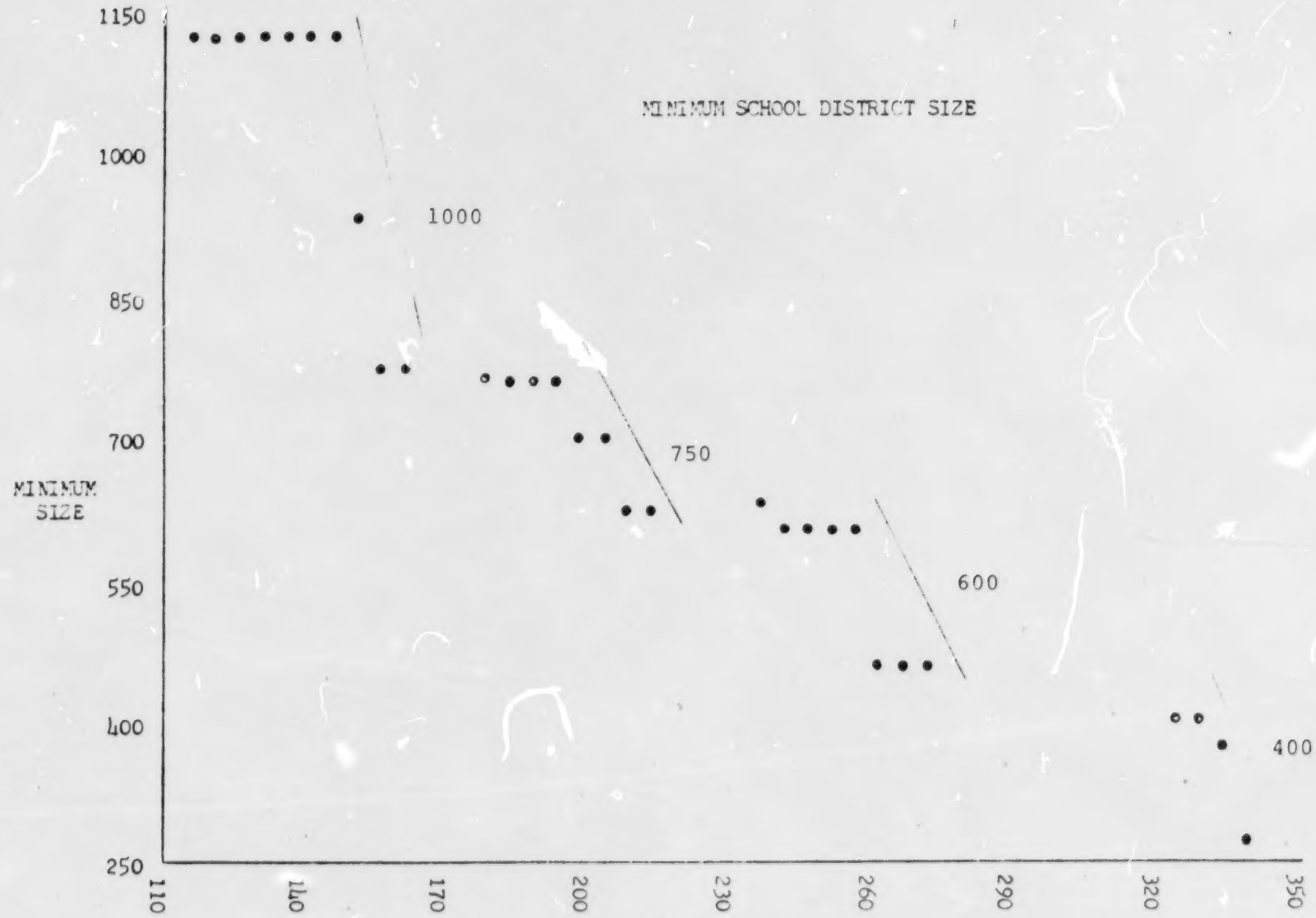

MINIMUM SCHOOL DISTRICT SIZE
1150
1000
850
700
550
400
250
MINIMUM SIZE
1000
750
600
400
110
140
170
200
230
260
290
320
350
NUMBER OF SCHOOL DISTRICTS

Figure 2

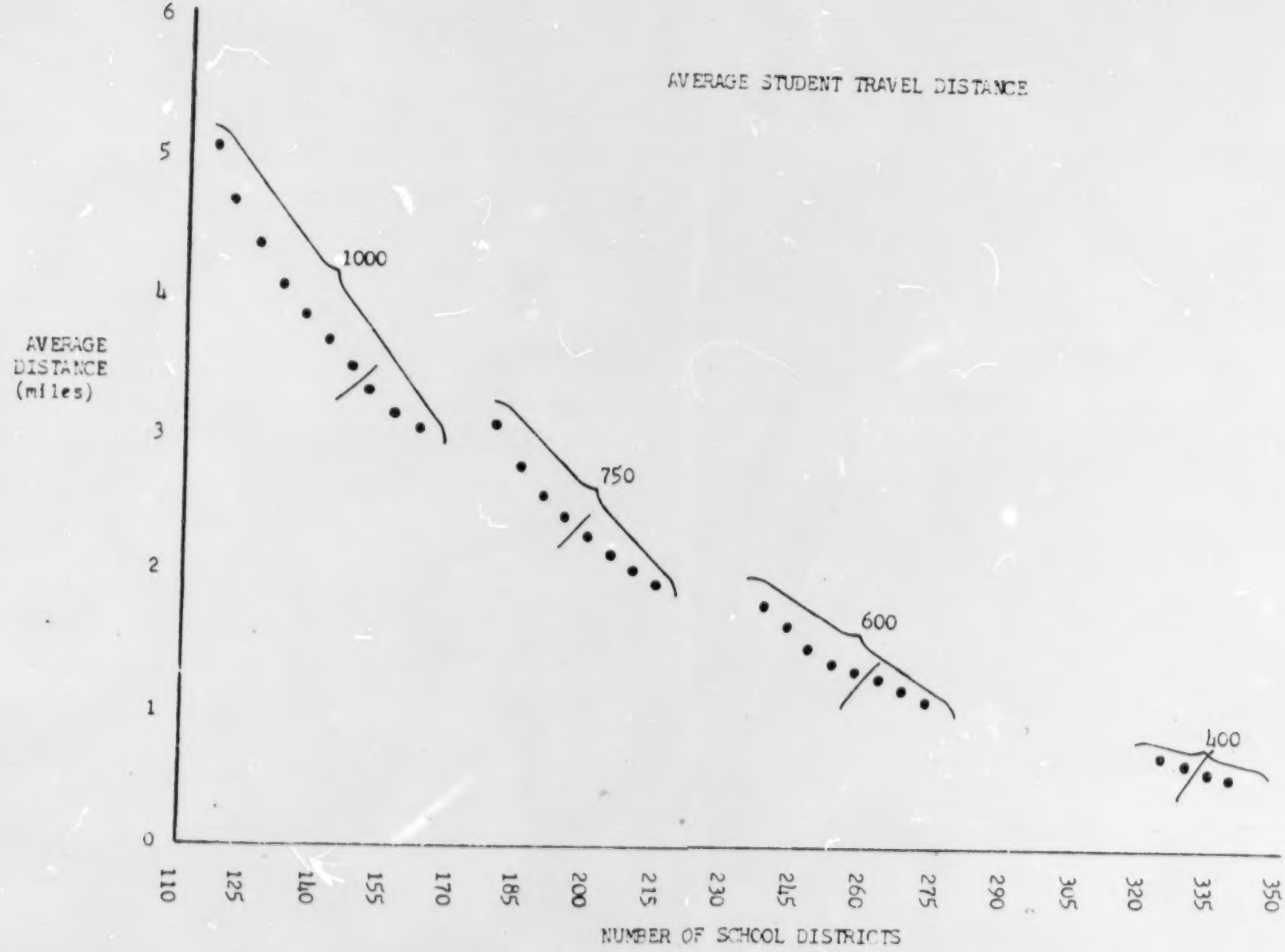

AVERAGE STUDENT TRAVEL DISTANCE
AVERAGE DISTANCE (miles)
0
1
2
3
4
5
6
1000
750
600
400
110
125
140
155
170
185
200
215
230
245
260
275
290
305
320
335
350
NUMBER OF SCHOOL DISTRICTS

Figure 3

Average Distance Among Affected Students

What appears to be moderate may on further examination look much more severe, and the distance effects of reorganization certainly look more severe when only the children who would actually travel farther are considered rather than averaging the increase over all children. Examining the effects on the impacted children is probably more pertinent than calculating the average for all children, particularly in light of the fact that reorganization has been proposed as a way of achieving greater equity in educational opportunity. Ignoring the plight of those who would bear the burden of extra travel would be to ignore an inequity.

The average travel of children who would be sent to a different high school in the four optimal reorganization schemes would be at least ten miles, the figure for the most moderate reorganization (to a 400 pupil enrollment limit). Many children, of couse, travel farther than that now, but this would be the average rather than most severe travel distance. Interestingly, reorganizing to achieve more severe enrollment constraints adds only marginally to the increased average travel (Figure 4). The 600 enrollment solution has an average of only 10.5 miles, the 750 pupil solution has a 12-mile average, and the 1,000 pupil solution has a 13-mile average among the affected children. The evidence suggests that if reorganization were to occur, little additional burden in distance would be borne by reorganizing to meet the more severe enrollment standard. The most moderate reorganization would provide schools of only forty percent the size but with seventy-seven percent the distance of the most severe reorganization.

Maximum Student Travel Distance

Even limiting the calculation to those students who would have to attend different schools, use of average distance as a measure of the impacts of reorganization ignores the

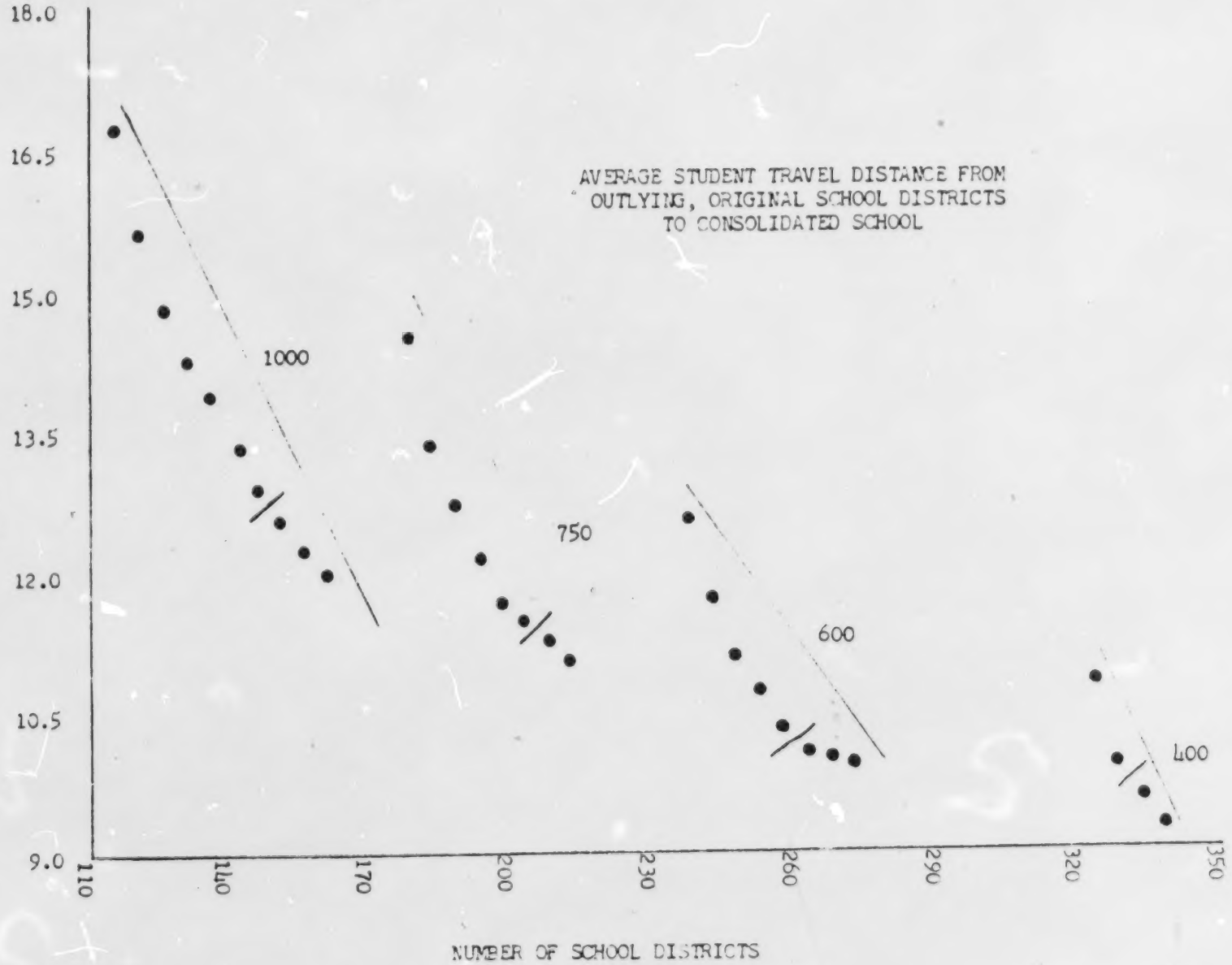

AVERAGE STUDENT TRAVEL DISTANCE FROM
OUTLYING, ORIGINAL SCHOOL DISTRICTS
TO CONSOLIDATED SCHOOL
AVERAGE
DISTANCE
(miles)
18.0
16.5
15.0
13.5
12.0
10.5
9.0
1000
750
600
400
110
140
170
200
230
260
290
320
350
NUMBER OF SCHOOL DISTRICTS

Figure 4

worst-off students. Many students would be forced to travel well beyond the average distance (Figure 5). Recall that this analysis assumed that new districts would be formed only by consolidating existing districts. Such an assumption precludes consideration of the very real possibility that in severe cases a district would be split. Because of this there is no reason to assume that reorganization must result in maximum distances as great as the ones in the solutions, but great is what the ones in the solution certainly are.

As was the case with average distance among affected students, the 400 enrollment solution is only marginally better in maximum distance than the 1,000 enrollment solution, twenty miles to twenty-six miles. Both the 600 and 750 enrollment solutions would have maximum distances of twenty-two miles. Using maximum distance as the criterion comparison, the 400 enrollment solution again would have almost as severe an effect on distance (seventy-seven percent) with only forty percent of the economies of scale benefits of the 1,000 enrollment solution.

OPTIMAL SOLUTIONS

The more severe the reorganization requirement, obviously the more the change that would be required. This section describes the change required in order to meet the target enrollments. Obviously, the change could be even greater - and indeed it would be if reorganization were to be completed without minimizing distances.

400 Pupil Solution: Even reorganizing so that all districts had only 400 pupils would reduce the number of school districts in Iowa to 328 from 449, a twenty-nine percent reduction. All sections of the state would be affected with the northwestern and extreme southern portions affected the most (Figure 6). A majority of the new districts would in fact be

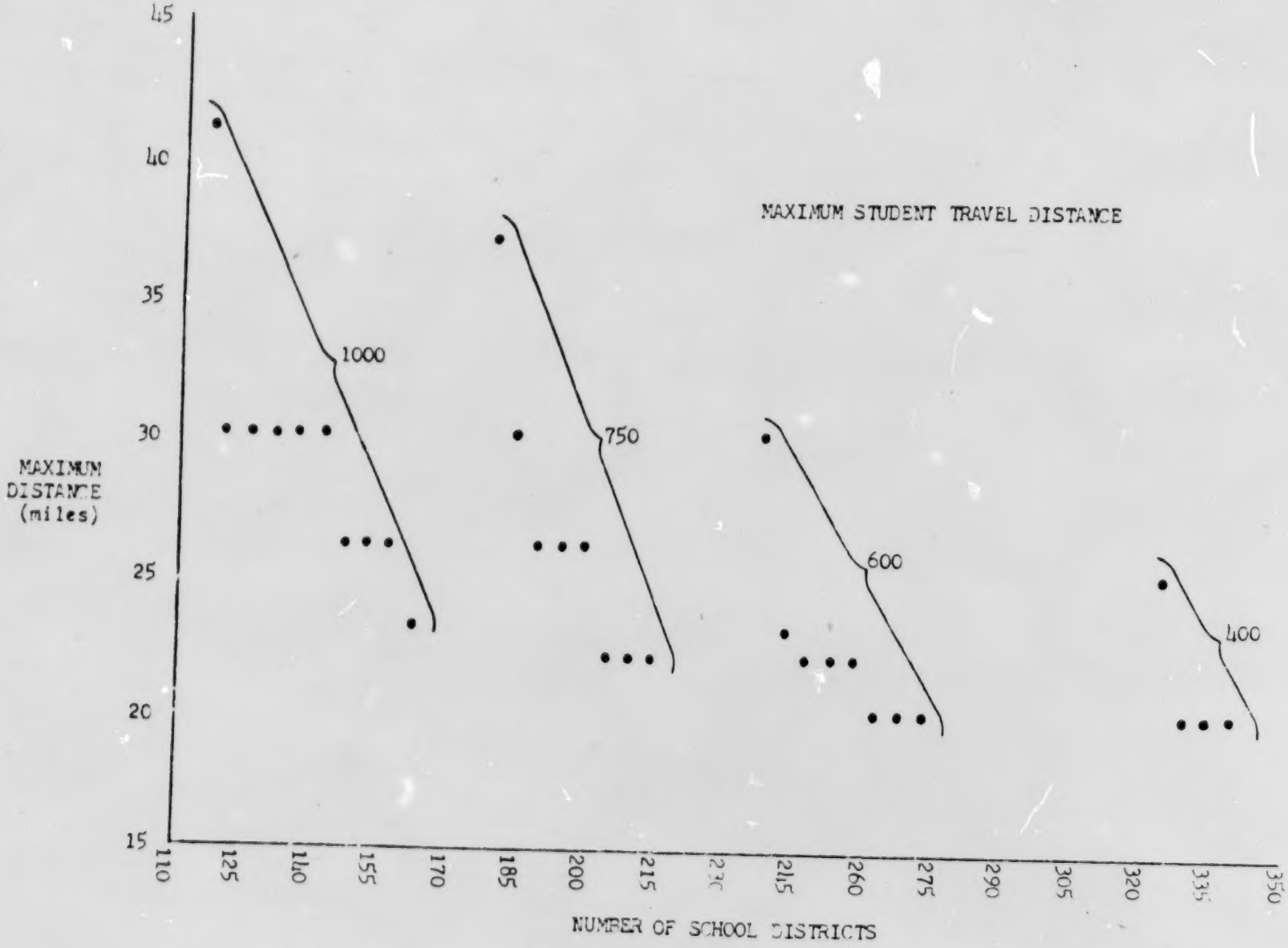
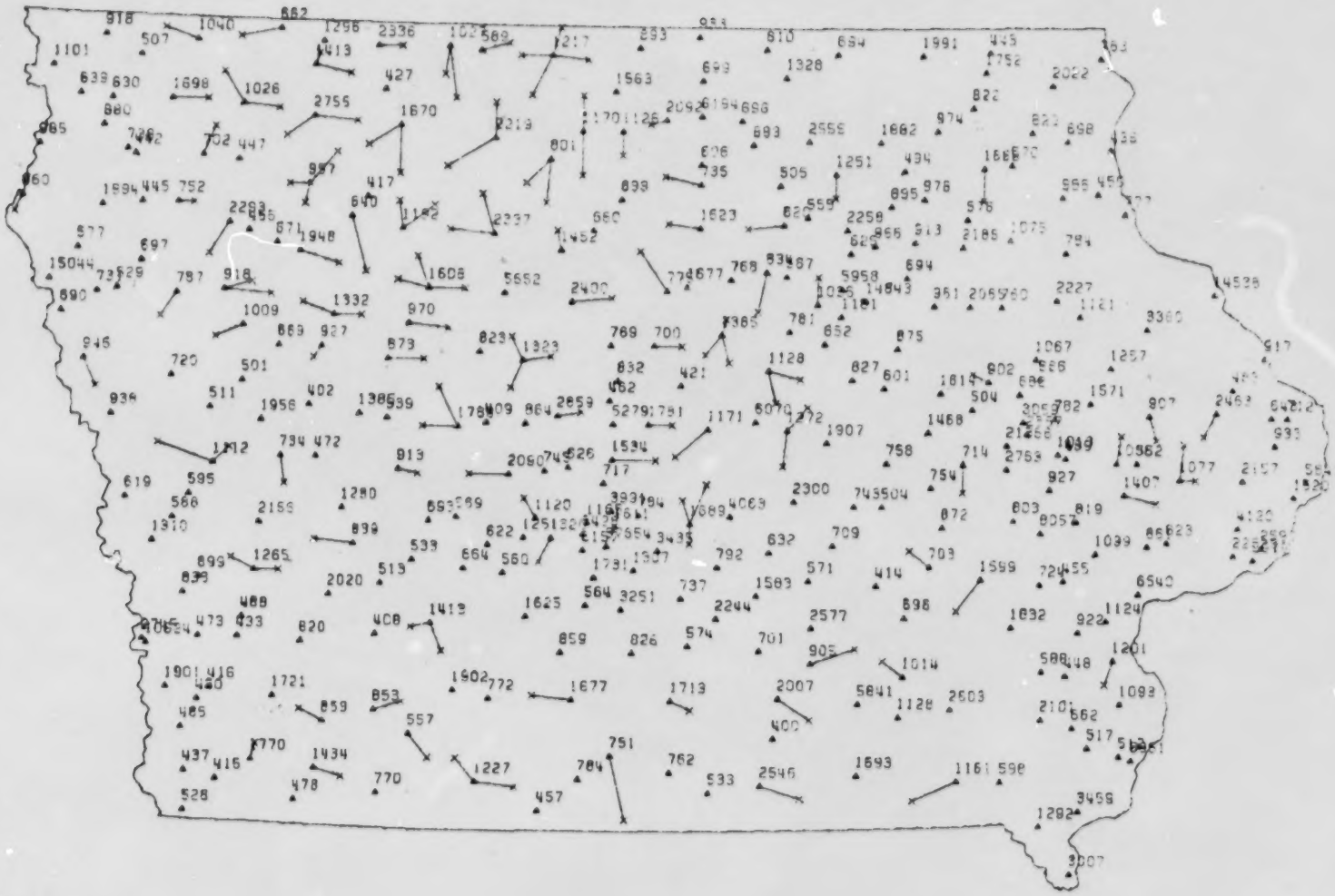

MAXIMUM STUDENT TRAVEL DISTANCE
MAXIMUM DISTANCE (miles)
45
40
35
30
25
20
15
1000
750
600
400
110
125
140
155
170
185
200
215
230
245
260
275
290
305
320
335
350
NUMBER OF SCHOOL DISTRICTS

Figure 5



328 DISTRICTS-ENROLLMENT GREATER THAN 400-MAXIMUM DISTANCE = 20 MILES

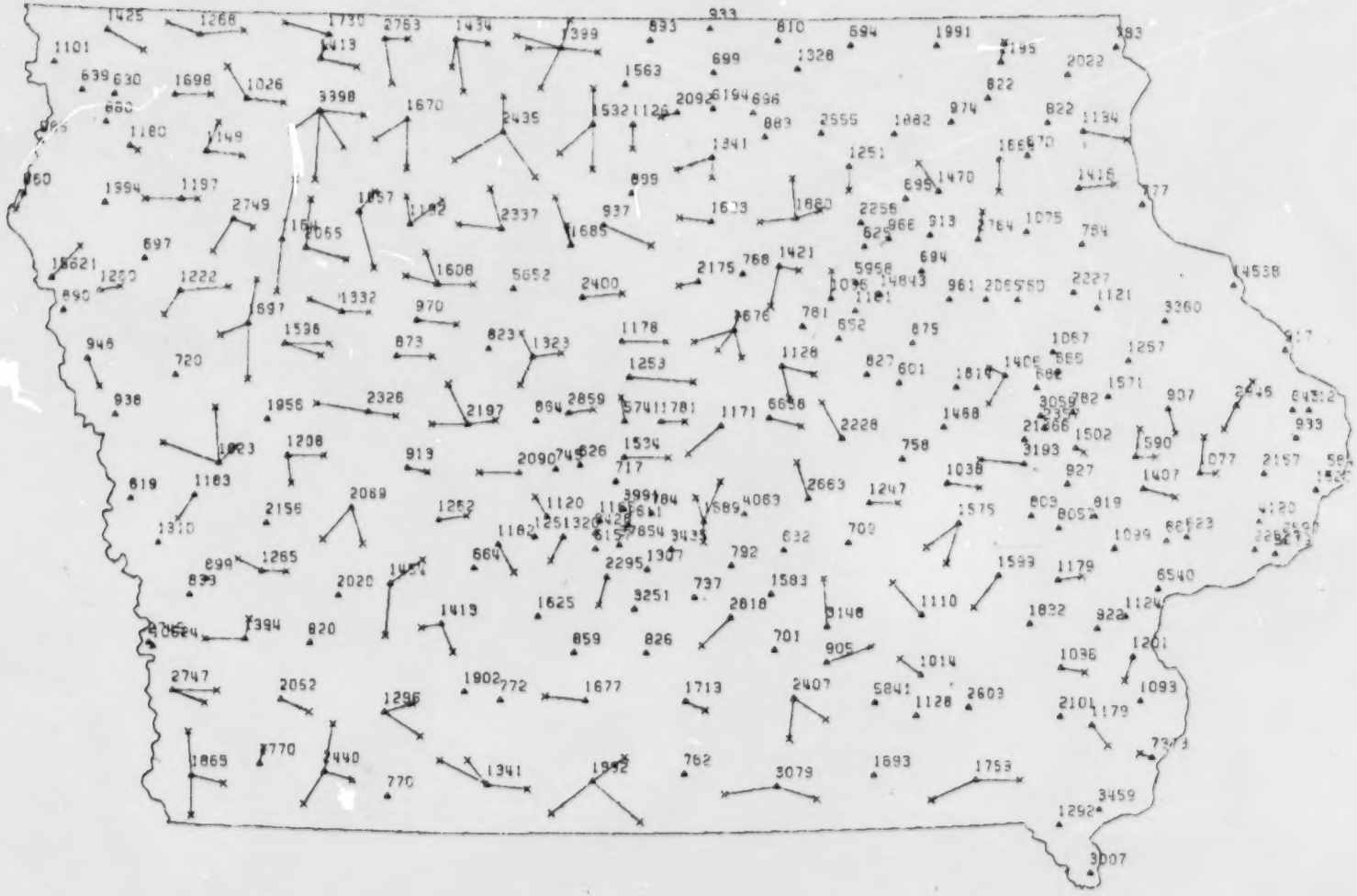
Figure 6

unchanged, and most of the changed districts would be the results of unions of adjacent districts -- sometimes two small ones, in other cases one with fewer than 400 pupils joining a larger neighbor. In only one instance were as many as five existing districts united in the solution, and that case involved five relatively small districts along the Minnesota border.

600 Pupil Solution: More widespread change would of course result from a reorganization which brought all school districts up to 600 pupils, but even in this solution the less densely populated western half of the state would undergo more change than the east (Figure 7). The number of districts in the state would be cut almost in half, down to 242, but of these 135 would be unchanged. The other 107 districts would be formed by joining the other 314 existing districts in combinations ranging from two to six -- the six being in the same Minnesota border area as the union of five districts in the solution to the 400 pupil constraints. This solution would couple a maximum distance of twenty-two miles with an average distance of 10.5.

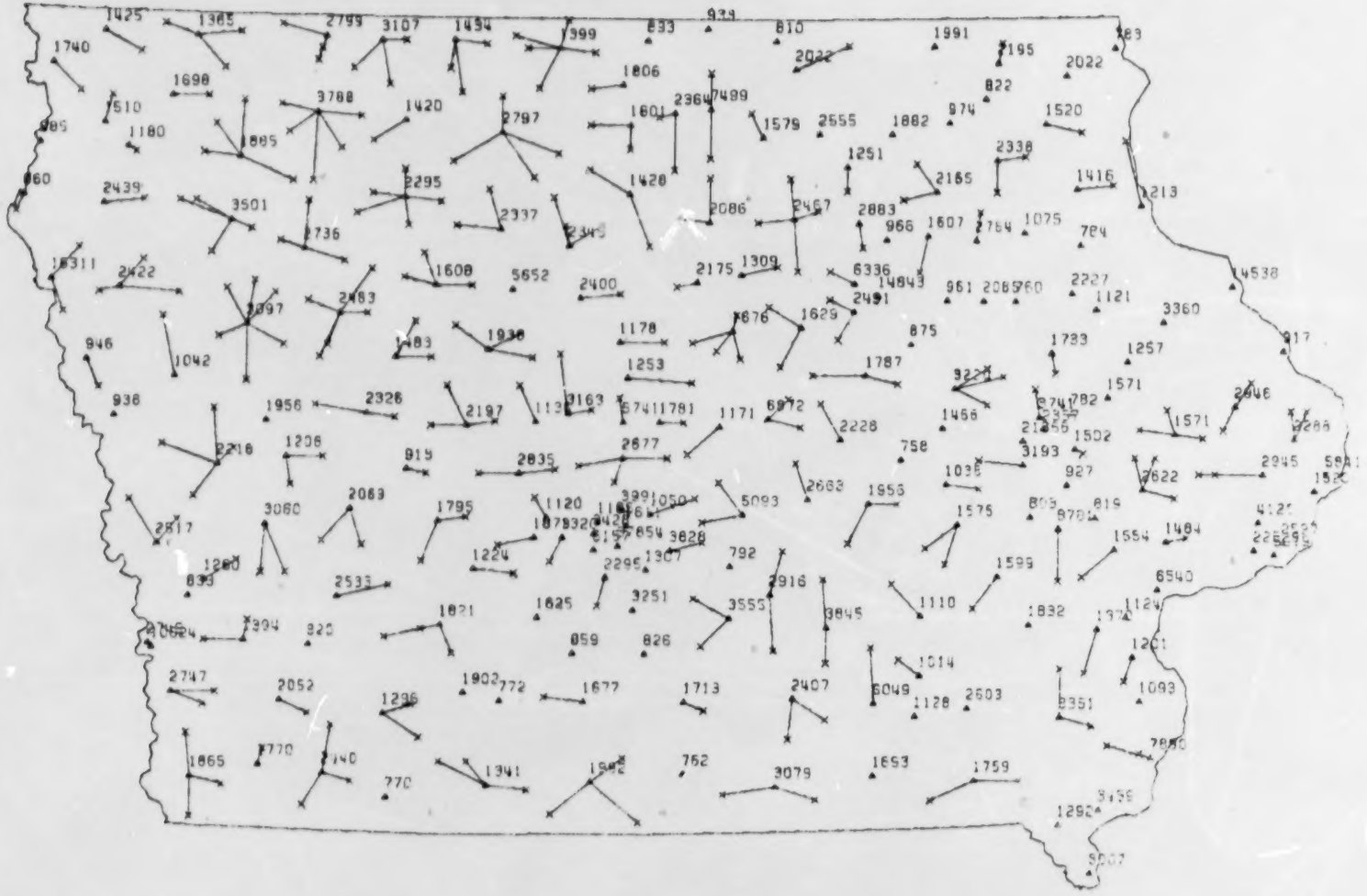
750 Pupil Solution: The third optimal solution, that with a minimum enrollment constraint of 750 pupils, would leave only seventy-two of the state's districts intact, the other 377 combining to form 131 new districts. Polk County and the eastern quarter of the state would have the most unaffected districts (Figure 8). In the northeastern quarter of the state most of the new districts would consist of four or more existing districts. Much more change would occur with a reorganization of this extent, but the distance effects would be only slightly more severe than in the 600 pupil solution -- average distance of twelve miles, maximum of twenty-two.

1000 Pupil Solution: Reorganizing to meet the most severe of the four alternative enrollment constraints, 1,000 pupils, would, of course, generate the most radical departure from the present.



242 DISTRICTS-ENROLLMENT GREATER THAN 600-MAXIMUM DISTANCE = 22 MILES

Figure 7



203 DISTRICTS-ENROLLMENT GREATER THAN 750-MAXIMUM DISTANCE = 22 MILES

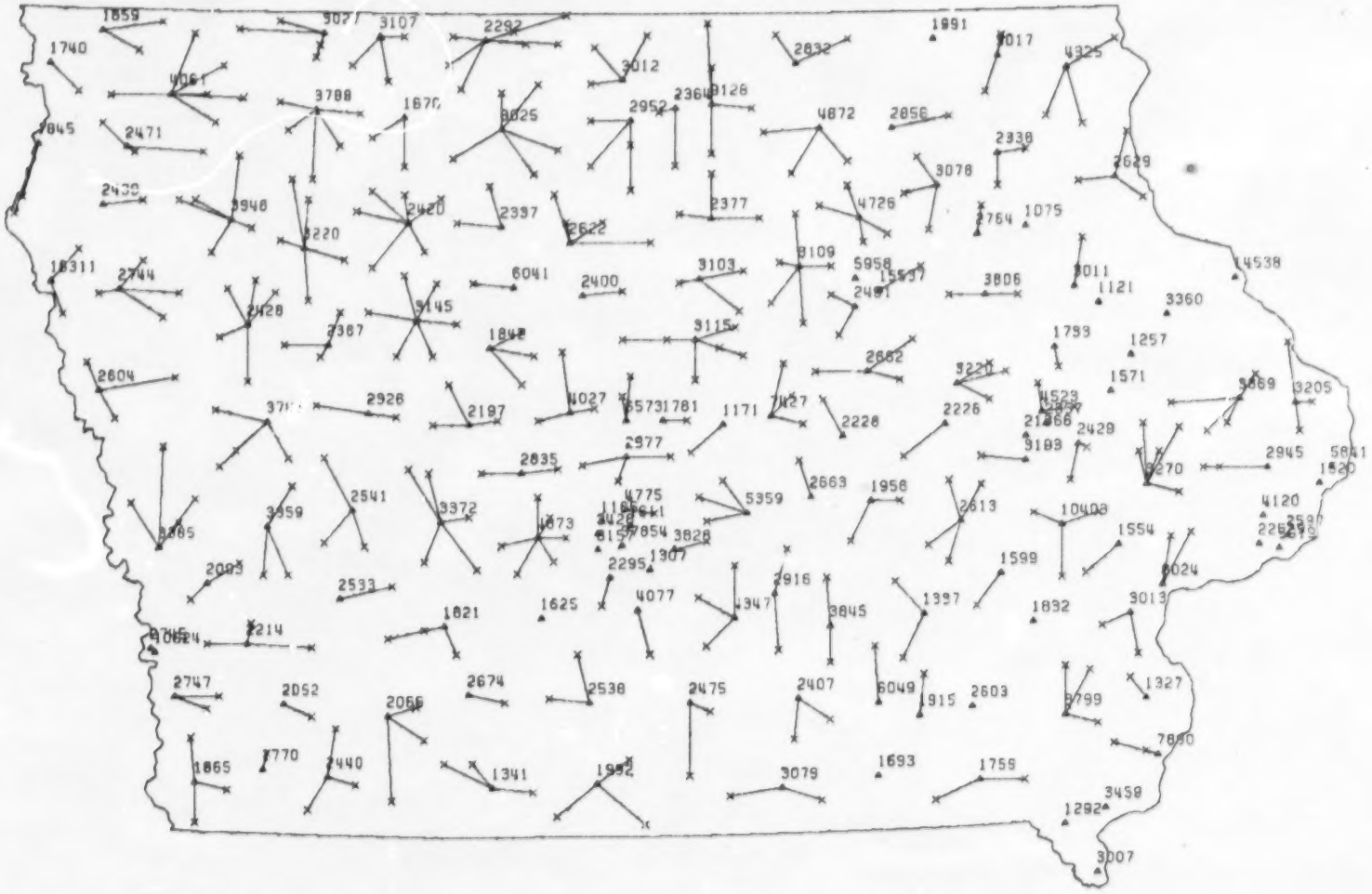
Figure 8

The optimal solution with this constraint left only thirty school districts intact. The other 419 were regrouped into 116 new districts, with up to eight joining together to form a new district (Figure 9). The distance consequences of reorganizing Iowa's school district so that all districts would have 1,000 children could be accomplished by consolidating districts such that the average distance to school for the affected children would be thirteen miles, the maximum distance twenty-six miles.

SET COVERING SOLUTIONS

These four sets of analyses, which comprise the first and largest section of the research, provide a means for examining the distance consequences if Iowa were to undergo a round of school district reorganization so that no school had fewer than a specified minimum enrollment. In effect, these analyses treated enrollment size as the independent variable, manipulating enrollment to see how the dependent variable, distance, responded. The results, as summarized in Figure 10, show that most of the distance costs which would be generated by an extensive reorganization would also be generated by a very moderate reorganization. Figures 3 through 5 show that some savings in distance can be made by relaxing the enrollment contraints in a few districts. Allowing some districts to drop from 1,000 to 850 pupils, for example, would permit a reduction of maximum distance from twenty-six to twenty-three miles. An alternative approach to holding the enrollment constraint fast and solving for distance is to employ a distance constraint and see what the enrollment consequences would be. This is the approach followed in the second set of analyses.

Given the projected enrollment distributions in the state, and given certain maximum distances for new districts, how could the state reorganize school districts so that it could move toward enrollment goals while setting maximum distance constraints? This can be solved as a set covering problem.[2]



146 DISTRICTS-ENROLLMENT GREATER THAN 1000-MAXIMUM DISTANCE = 26 MILES

Figure 9

Enrollment Level	Maximum Distance	Maximum Distance for Those Affected by Reorganization
400	20	10.0
600	22	10.5
750	22	11.5
1,000	26	13.0

INCREASING DISTANCE WITH INCREASING ENROLLMENT

Figure 10

The three distance standards which were examined were ten, fifteen and twenty miles. The ten mile set covering problem could be solved through the deployment of 305 centers which would serve student bodies as small as 97 and as large as 37,000. The average increase in distance would be just under a mile for all students and eight miles for students assigned to a new center.

Only 190 centers would be required to solve the 15 mile set covering problem, enrollments ranging from 155 to 37,000. Distance increases would approach two and one half miles for all students and eleven miles for those students assigned to a new attendance center.

Iowa could provide schools for all children in the state within twenty miles of existing high schools by using only 155 sites. Such a solution would generate a three mile per pupil distance increase when all children are considered and an increase of over twelve miles for the students assigned to new centers.

DISTANCE-ENROLLMENT TRADE OFF

Rather than treating either enrollment size or distance as paramount, with the other simply responding to the one deemed most important, it is possible to treat them both as important, achieving rigorous standards for both where possible, relaxing the standards where not. The final set of analyses examined what could be accomplished if Iowa school districts were reorganized with explicit recognition of the dual importance of overcoming the problems of the smallest school districts without creating the inequity of inordinately long bus rides. Such a solution bows to the uneven distribution of population in the state. Two trade-off or constraint relaxation solutions were attempted. One separated rural and urban districts. The other, and more successful one, allowed the solution to join districts which best fit the objective function -- minimizing average distance.

Urban Separation Solution

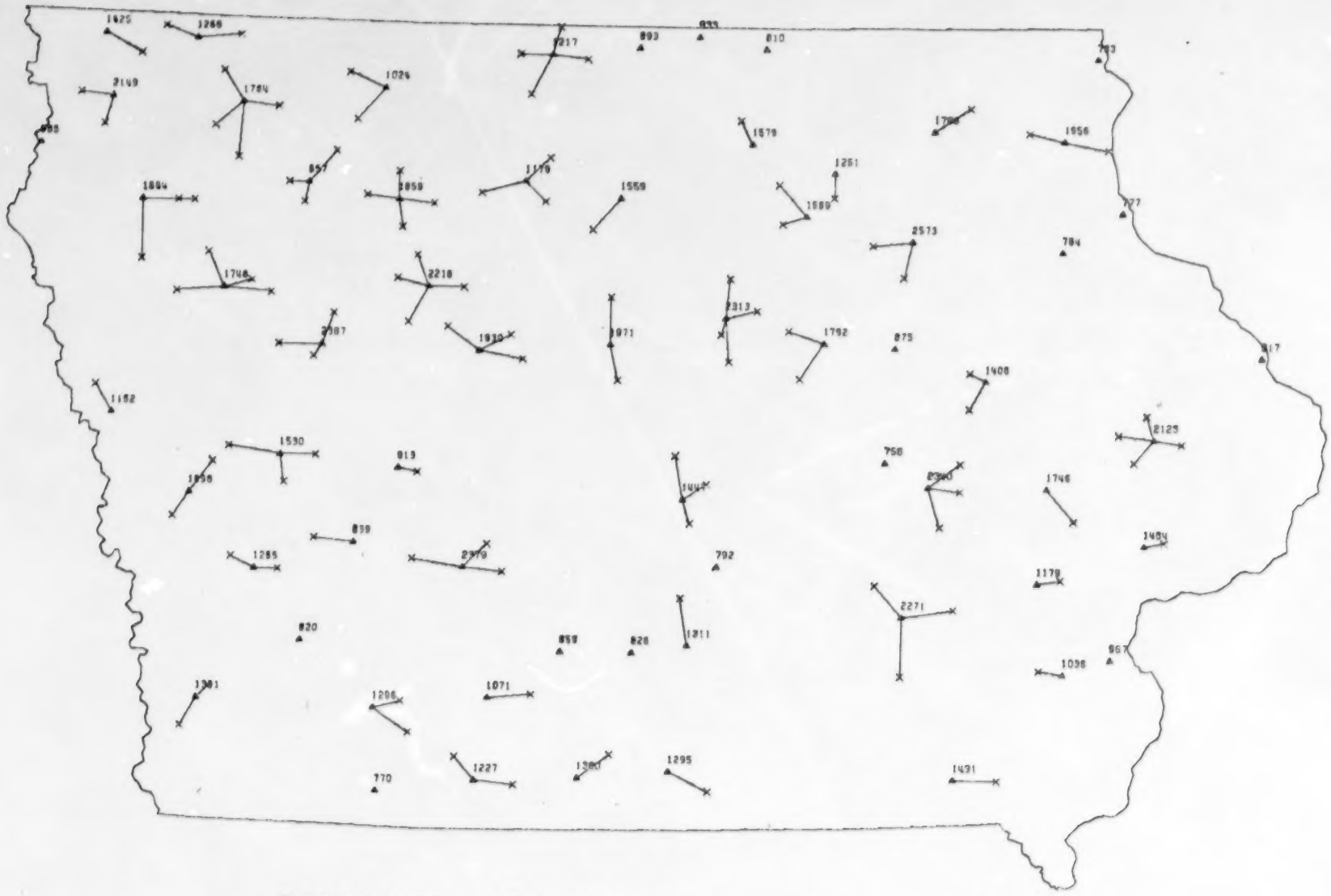
The first analysis began by finding all districts or combinations of districts which are projected to have 1,000 pupils within ten miles (Figure 11). Included were over 200 of the existing districts and the overwhelming preponderance of the projected enrollment. These districts were then removed from analysis on the grounds that many small town and rural districts do not want to be consolidated with urban districts. The second step found among the remaining districts those which could have 750 pupils within fifteen miles (Figure 12). Some districts were within fifteen miles of centers which met the 1,000-students-within-ten-miles criteria of the first step, but in this "urban separation" solution, these districts were not assigned to those meeting the first step criteria. In the third step, the constraints were reduced to enrollment of 600 within twenty miles. At the conclusion of this stage, a few districts were trapped with no feasible solution because their possible partners had been removed in earlier steps. The final step was a relaxation of constraints to enrollment of 400 and distance of twenty-five miles (Figure 13).

Constraint Relaxation Solution

The other solution in this set of analyses did not prevent the districts found in early steps from having other districts assigned to them in later steps. There was no artificial separation of urban and rural districts in this solution, simply an effort to meet both the distance and enrollment criteria with successively more feasible constraints. The first step was the same as in the urban separation solution: finding all districts and combinations of districts with 1,000 pupils within ten miles. The second step lowered the constraints again to 750 and fifteen, but those districts within fifteen miles of a large district -- and no nearer any other district -- were assigned to the large neighbor this time. Then the constraints

DISTRICTS WITH 1000 ENROLL. IN 10 MILES

Figure 11



DISTRICTS WITH 750 ENROLL. IN 15 MILES

Figure 12

DISTRICTS WITH 600 ENROLL. IN 20 MILES

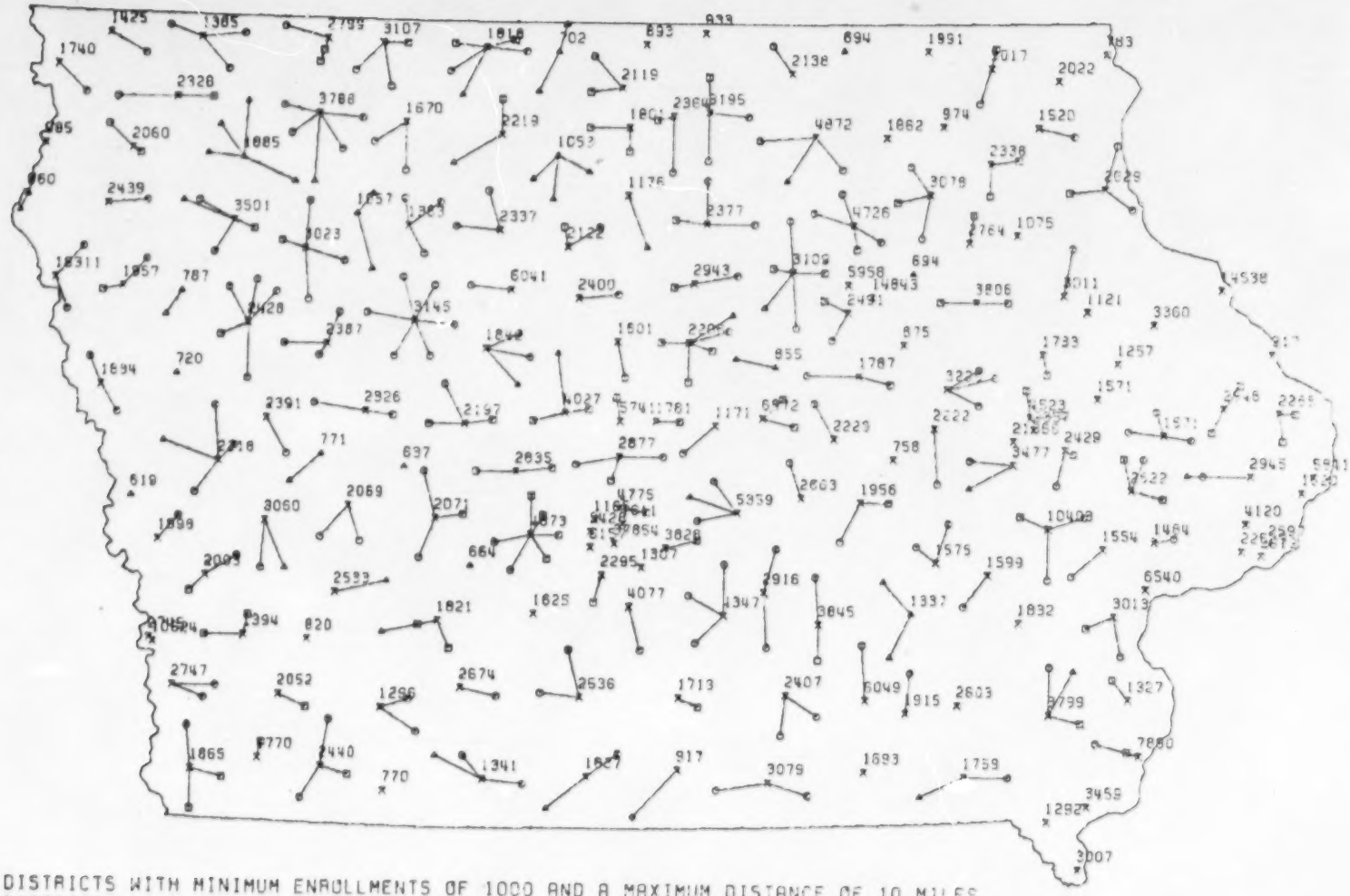
Figure 13

were reduced to 600 pupils and twenty miles and finally an enrollment of 400 and distance of twenty-five miles (Figure 14). This solution wound up with 177 districts, some of which added existing districts each of the first three steps. The total travel distance was much less than in the optimal 1000 pupil solution of the first analysis, as well as less than the 750 pupil solution of that analysis. No district would be forced to extreme limits (Figure 15). An obvious option for the state, then, would be to reorganize in a way that recognizes the importance of both sufficient enrollments to enable the provision of a comprehensive curriculum and sufficient access to facilities to enable students and communities to gain the benefits from that curriculum.

EFFECTS OF COUNTY SCHOOL DISTRICTS

The analyses discussed thus far were of course controlled by the constraints and objectives of the alternatives considered. Obviously many other alternatives and objectives would be possible. One could, for example, examine the consequences of erasing all school district boundaries and locating schools and allocating townships and towns to schools in an optimal fashion. Such a study was regarded as too unrealistic as well as too expensive to conduct given the limitations of the State Equalization Project. Another alternative which did not present such stringent analytical problems would also require a complete break with existing district boundaries. That would be to replace the existing school districts with a single district in each county. As anyone familiar with Iowa school districts knows, few school districts now follow county boundaries even for a portion of the district boundary. Two districts (Davis County and Fairfield) approximate county districts, but even they deviate somewhat from the county limits.

What would be the enrollment and distance consequences of adopting 99 school districts, one for each county? Every county


DISTRICTS WITH MINIMUM ENROLLMENTS OF 1000 AND A MAXIMUM DISTANCE OF 10 MILES
DISTRICTS WITH MINIMUM ENROLLMENTS OF 750 AND A MAXIMUM DISTANCE OF 15 MILES
DISTRICTS WITH MINIMUM ENROLLMENTS OF 600 AND A MAXIMUM DISTANCE OF 20 MILES
DISTRICTS WITH MINIMUM ENROLLMENTS OF 400 AND A MAXIMUM DISTANCE OF 25 MILES

164 DISTRICTS (CONSTRAINT RELAXATION) MAXIMUM DISTANCE = 25 MILES

Figure 14

lan	Number of Miles					
	0	1-5	6-10	11-15	16-20	21-25
,000	412,571	3,584	41,067	69,897	28,711	6,828
750	459,225	2,674	41,119	50,247	9,653	155
600	494,545	4,736	31,477	28,847	3,313	155
400	528,878	2,833	18,570	11,245	1,547	0
rban Separation	461,998	5,568	56,131	31,268	5,301	1,058
onstraint Relaxation	433,244	3,584	45,149	73,308	7,633	155

DISTANCES CHILDREN WOULD TRAVEL TO SCHOOL -- ALL OPTIONS

Figure 15

has over 1,000 children between the ages of five and seventeen, so the number of pupils would surpass even the most stringent limit considered in the preceding analyses. Only where sizable proportions of the children in sparsely populated counties attended parochial schools would the enrollment fall below 1,000.

Meeting the distance constraints of the earlier analyses would be a more difficult matter. Assuming that the school would be located at the county seat or a centrally located large town, some children would have to travel more than twenty miles in almost every county in Iowa (Figure 16). Most counties would have maximum distances in the low or mid-twenties. In all but the smallest counties, the distance problem could be alleviated by having more than one school at each level -- elementary, middle and high school -- and such a solution could be used in the small counties, but some teachers would probably have to teach at more than one building given such a system.

An alternative to having a single district for each county would be to have the county provide the base but allow for more than one district if enrollment justified it. This alternative would achieve the enrollment levels desired yet increase distances only where enrollment was low. Under either this or the one-district-per-county alternative, school administration could be much more effectively coordinated with other public services, especially those provided by the county. Roads and land use planning are two obvious areas which are controlled by counties but have a major influence on school districts.

SUMMARY

Equalization of educational opportunity is a multi-faceted, complex goal. Locational issues affecting children's opportunities to learn and hence the ways in which school districts are organized is a topic of interest. Schools which

Figure 16

MAXIMUM DISTANCES FROM COUNTY SEAT OR SURROGATE

IN IOWA'S MOST SPARSELY POPULATED COUNTIES

County	1970 Population	County Seat	Surrogate	Maximum Distance
Adair	9,487	Greenfield		26
Adams	6,322	Corning		22
Audubon	9,595	Audubon		25
Clarke	7,581	Osceola		22
Davis	8,207	Bloomfield		23
Decatur	9,737	Leon		25
Fremont	9,282	Sidney		26
Ida	9,282	Ida Grove		27
Osceola	8,555	Sibley		28
Ringgold	6,373	Mt. Ayr		26
Taylor	8,790	Bedford		27
Van Buren	8,643	Keosauqua		23
Wayne	8,405	Corydon		24
Worth	8,968	Northwood	Kensett	21
Monroe	9,357	Albia		24
Louisa	10,682	Wapello		31
Lucas	10,163	Chariton		23
Howard	11,442	Cresco	(Davis Corners)	33(24)
Madison	11,558	Winterset		24
Mills	11,832	Glenwood	Malvern	25

are too small cannot provide a comprehensive curriculum unless they have more money per pupil than schools which are not so small. On the other hand, enlargement of the area served by a school (and school district) usually results in increased time and inconvenience consumed getting to school. Spending more time than other children simply getting to the schoolyard is another inequity. This study has examined the union of these inequities, measuring the distance effects of increasing district sizes so that a series of enrollment minima would be met. The study has shown that the average distance increase for children would be minimal, simply because most children would not be affected. Among reassigned children, however, the impacts would be significant, averaging more than ten miles for most alternatives. The analyses also showed that most of the distance effects would occur even with a moderate increase in district enrollment. If reorganization were to occur, small marginal increases in distance would result from setting enrollment minima at 1,000 or 750 pupils rather than 600 or 400. More attractive than a single enrollment standard, however, may be a combination of enrollment and distance standards. Areas with dense enough populations to reach an enrollment standard within a modest distance constraint could be required to reorganize so that they met the standard. Elsewhere both the enrollment limit and distance constraint could be relaxed. This way the disbenefits of having schools too small could be traded off against the disbenefits of having distances too great.

All of the work described in this report is aimed at finding out what would happen if reorganization of school districts were to occur in Iowa. The report is not a recommendation; rather it is an application of location-allocation methodology to simulate what would happen if reorganization were to occur. Without minimizing distance, the trip lengths of a resulting system would be longer than those reported. Any such increases in distance, as well as the findings of this report, need to be considered in the light of any other objectives of school district organization.

NOTES

1. The function is specified as follows:

$$\text{Minimize } (Z) = \sum_{i=1}^{n} \sum_{j=1}^{n} a_i d_{ij} x_{ij}$$

$$\text{subject to } \sum_{j=i}^{n} x_{ij} = 1 \quad i = 1, 2, \ldots, n$$

(i.e., each demand point assigned to one and only one node)

$$x_{jj} \geq x_{ij} \quad i, j = 1, 2 \ldots, n' \; i \neq j$$

(no demand will be assigned to a supply point that does not also serve itself)

$$\sum_{j=1}^{n} x_{jj} = m$$

(sum of the positive diagonal elements equals m; that is, every supply point serves its own demand)

$$x_{ij} \geq 0 \quad i, j = 1, 2, \ldots, n$$

where a_i = the demand population at node i;

d_{ij} = the shortest time (distance) from node i to node j;

x_{ij} = 1 if node i assigns to a certer at j, 0 otherwise;

n = the number of nodes of the network; and

m = the number of central facilities to be located.

Notes continued

2. The formulation is the same as in 1, with the constraint that all:

$$x_{ij}\ d_{ij} \geq s \quad (i, j = 1, 2, \ldots, n)$$

where s is some maximum distance. Now determine the number of school districts needed such that no students will have to travel further than s distance units.